

TECHNOLOGY UTILIZATION

MATERIAL CUTTING, SHAPING, AND FORMING

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SHAPING, AND FORMING: A COMPILATION  
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A COMPILATION



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# Foreword

The National Aeronautics and Space Administration and the Atomic Energy Commission have established a Technology Utilization Program for the rapid dissemination of information on technological developments which have potential utility outside the aerospace and nuclear communities. By encouraging multiple application of the results of their research and development, NASA and AEC earn for the public an increased return on the investment in aerospace and nuclear research and development programs.

This document is intended to provide such information on technology having to do with the cutting, shaping, and forming of materials and the equipment and techniques required to reduce these materials to usefulness in a variety of applications.

The Compilation is divided into four sections. In the first section, the use of molds, electrical fields, and mechanical devices are related to the forming of certain materials for a number of uses. Section two presents material cutting methods by a number of devices including borers and slicers, plus two chemical approaches. In the third section, shaping and fabrication techniques are featured that involve such items as tubing, honeycomb panels, and ceramic structures. The final section covers materials characteristics important to the cutting, shaping, and forming of the materials discussed.

Additional technical information on individual devices and techniques can be requested by circling the appropriate number on the Reader Service Card included in this Compilation.

The latest patent information available at the final preparation of this Compilation is presented on the page following the last article in the text. For those innovations on which NASA and AEC have decided not to apply for a patent, a Patent Statement is not included. Potential users of items described herein should consult the cognizant organization for updated patent information at that time.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this Compilation.

Jeffrey T. Hamilton, *Director*  
*Technology Utilization Office*  
*National Aeronautics and Space Administration*

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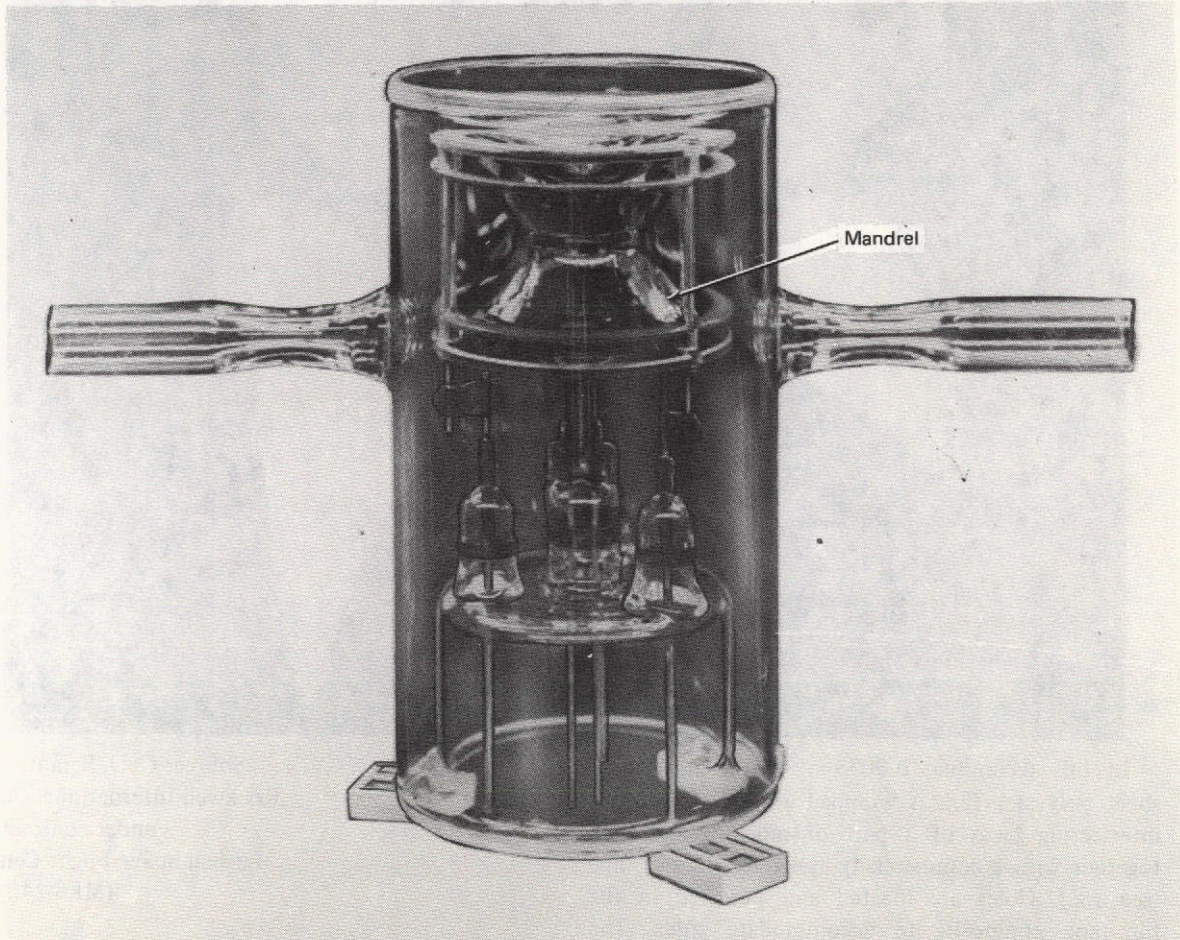
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# Section 1. Material Forming Techniques

## FLOW-FORMING ASPHERIC GLASS SURFACES



Ion resonance tubes require glass hyperbolic surfaces in aspheric configurations to extremely fine tolerances. This flow-forming method provides a simple and inexpensive means of producing such surfaces in thin glass components. The method eliminates the need for expensive polishing operations that would be necessary if the curves were ground into the glass. Since the glass is in a molten state when formed by this method, the product has a fire-polished surface.

A stainless steel mandrel is designed and machined to the proper aspheric configuration by use of a computer-programmed machine. A separating medium of graphite on the mandrel permits easy removal of

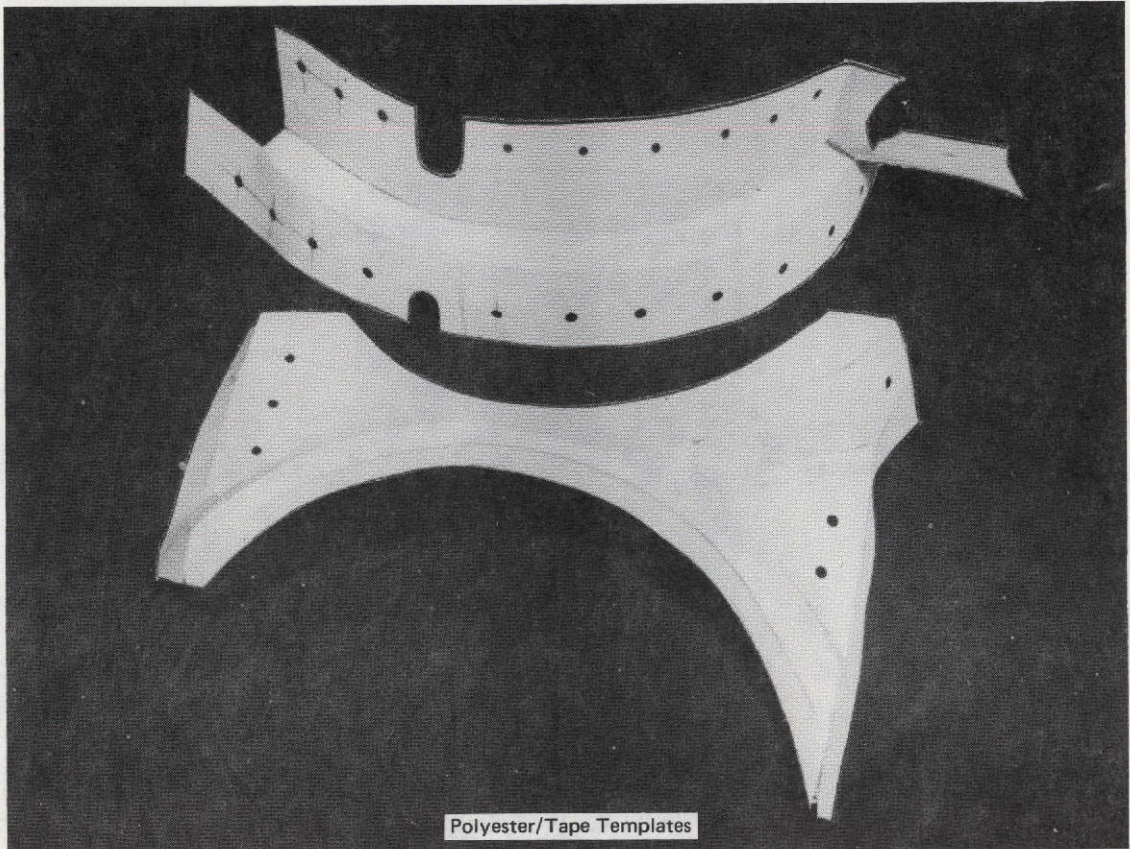
the finished product. The mandrel and glass are mounted in a glass-blowing lathe (see fig.) and heated until the glass flows to conform to the aspheric contour of the mandrel. Depending on the configuration, the glass is pressed, blown, or drawn to the mandrel form. When cooled the glass is readily removed from the mandrel, and the process may be repeated, on a production basis.

Source: R. Harris, R. Hessler, G. Bergen, and  
A. Walch

Goddard Space Flight Center  
(GSC-11139)

*Circle 1 on Reader Service Card.*

## FABRICATING LOW-COST LAYOUT TEMPLATES



In this technique, 0.0075-in. (0.190-mm) thick sheet polyester film is wrapped around the various intersecting faces of a part or mockup and held together with a commercially-available adhesive tape (see fig.). Holes are located and punched in the film/tape composite to accommodate studs. The resultant template is flexible and permits slight variations in production parts, while consistently locating studs within manufacturing tolerances.

Source: C. O. Scranton of Rockwell International Corp. under contract to Marshall Space Flight Center (MFS-24016)

*Circle 2 on Reader Service Card.*

## AN ELECTROFORMING TECHNIQUE

An exact duplicate of a machined surface is required for use as a mandrel in electroforming of complex shapes. Prior art, such as used in manufacturing phonograph records, included machining a plastic model on which a conducting silver coating is deposited. A metal negative is then electroformed, the silver film is removed, and a positive is electroformed from the negative. The silver coating, while formed as thin and smooth as practical, often

contains pores or rough areas, and these are transferred to the negative, thus producing an imperfect positive.

In this innovation, the plastic model is coated with a chemically-deposited silver film, using a minimum of chemical treatment. Electrotpe manufacturing techniques are sufficient. Adhesion of the silver is not a critical factor, but the film should not peel. A low-stress copper is next deposited electro-

chemically to adhere to the silver. The copper shell with its adherent silver is then separated from the plastic model and nickel deposited on the silver coating that remains on the copper. The copper and silver are chemically dissolved, leaving an exact nickel replica of the plastic model.

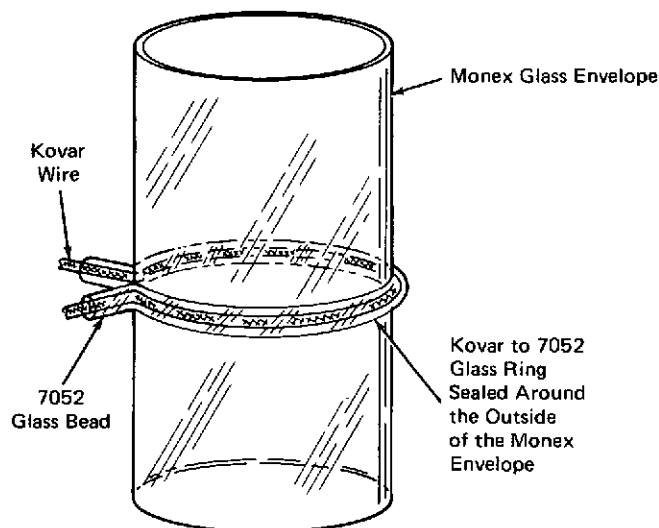
The excellent repeatability of the replica is due to the lack of dependence on quality of the silver film (smoothness and absence of pores). Any imperfection in the silver interfacing with the copper is un-

important because the nickel replica is deposited on the side that originally interfaced with the plastic model. Pores will have been filled during the copper plating.

Source: F. Goebel of  
Battelle Memorial Inst.  
under contract to  
Goddard Space Flight Center  
(GSC-11369)

*No further documentation is available.*

## CONTROLLED OPENING OF GLASS ENVELOPES



Hammer type bearings are normally used to open glass envelopes at a specific time so that the enclosed instrumentation may be exposed to the environmental situation at a precise time. The method, however, is somewhat imprecise and results in some shipping that could interfere with sensitive instrumentation.

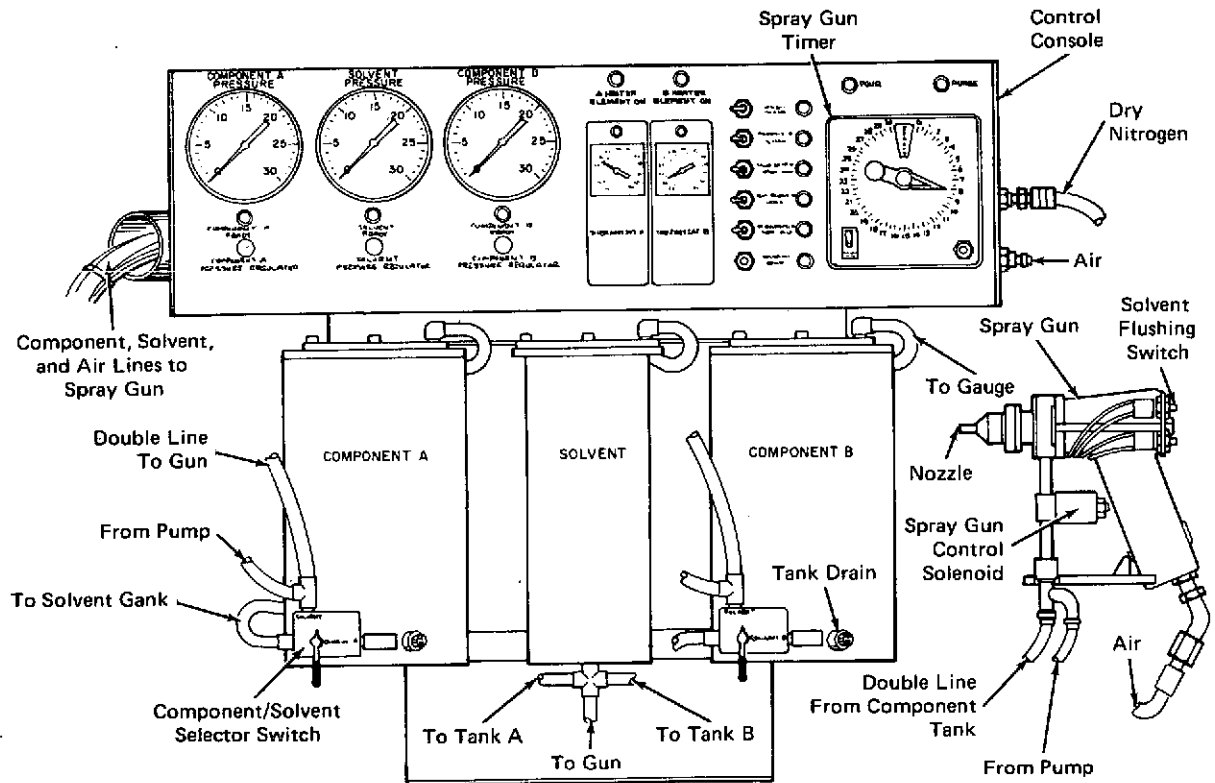
This innovation avoids such problems by making use of a mismatch in the coefficients of expansion of two materials. The body of the envelope is a commercially available borosilicate glass. Around its perimeter at the desired point an electrical conductor

is oven annealed in a glass sheath of dissimilar expansion coefficient. At the desired moment, voltage is applied to this conductor, and the pressure, resulting from the difference in coefficients of expansion, cracks the envelope uniformly, exposing the enclosed instrumentation to the environment to be sampled.

Source: G. Bergen  
Goddard Space Flight Center  
(GSC-11286)

*No further documentation is available.*

## PORTABLE URETHANE FOAM GENERATOR/DISPENSER



This innovation is a small, lightweight and compact generator and dispenser of urethane foam for insulating cryogenic fluid system components in the field. Commercially available urethane foam generating/dispersing systems exist but are stationary in nature and designed for bulk production.

The purpose of this innovation is the application of uniform coatings of insulation on cryogenic piping, valves, and tanks during fluid transfer and ground hold periods related to the launching of a space vehicle. Potential application of this versatile device, in industrial handling of cryogenic fluids, is readily apparent.

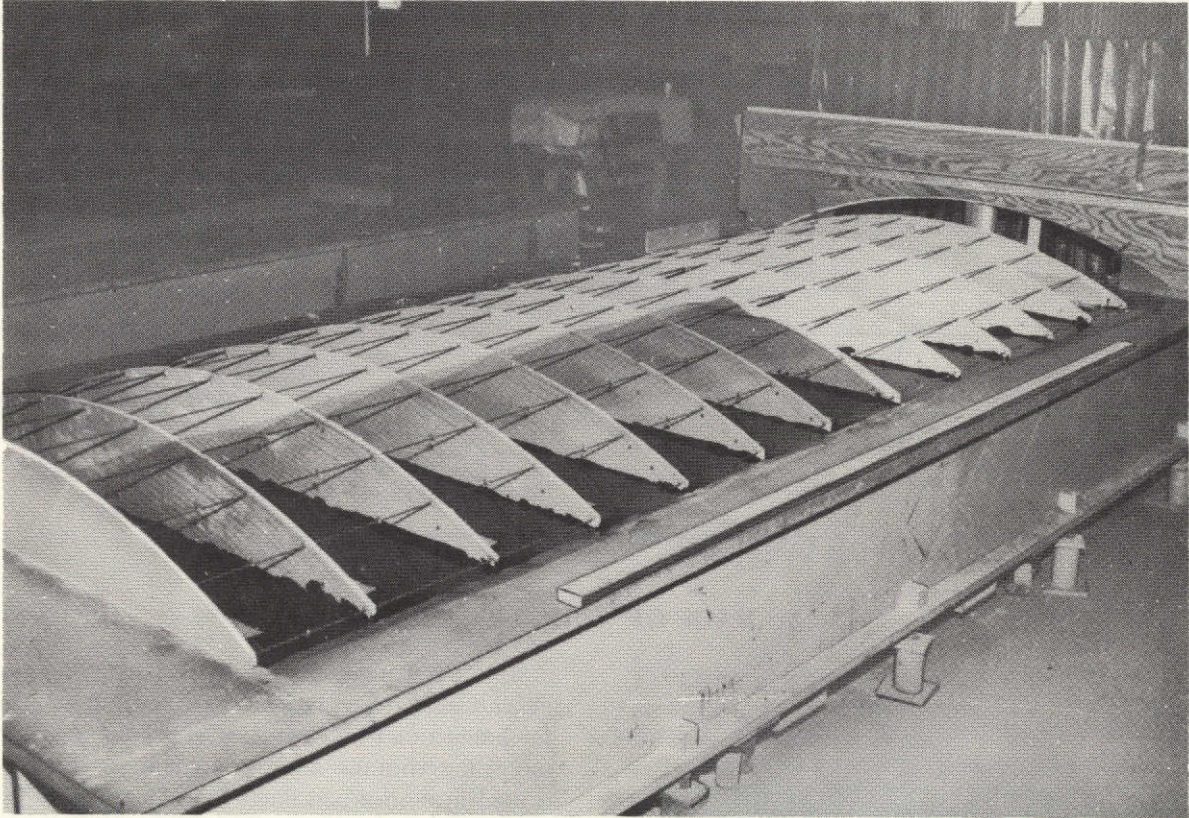
The system is shown in the illustration. In operation, the two foaming components, A and B, are contained in separate tanks and are pressurized with dry nitrogen gas for delivery to a hand-held spray gun that dispenses the foam. The spray gun features an air-driven rotary mixer and a solenoid valve that is controlled by a timer for automatic control of foam delivery volume. A third tank

contains a solvent, also under dry nitrogen gas pressure, that is used to clear all lines and the spray gun prior to long non-use periods. The foam components, A and B, are maintained at constant temperature in the tanks and transfer lines by a circulating, heated water system controlled by two thermostats mounted on a control console, which also mounts the foam-dispensing timer, pressure gauges for the three tanks, plus related switches and indicator lights. Foam component mix ratio can be controlled within discrete tolerances by varying component tank A and B pressures together with manual manipulation of the tank valves.

Source: R. King of  
Bendix Corp.  
under contract to  
Johnson Space Center  
(MSC-13588)

*No further documentation is available.*

## PLASTIC SHEETS USED IN FABRICATION OF TOOLING



Bulkheads of Sheet Fiberglass

In the fabrication of plaster masters, bulkheads must be made to support the plaster for the final sweep. In the past, such bulkheads were made of steel or aluminum. Due to their tendency to expand and contract because of temperature changes, they would, in time, cause cracks in the plaster, thus making the tooling useless.

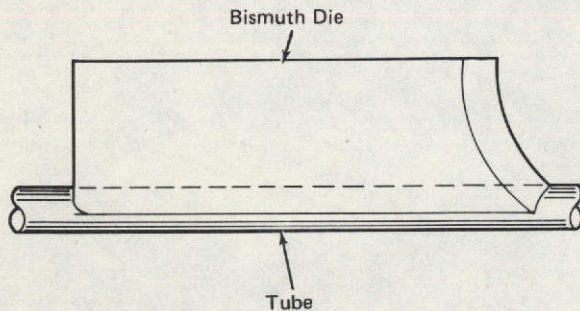
In this innovation, sheet fiberglass is used (see fig.) to form the bulkheads. This produces excellent plaster masters that can be used indefinitely in an environment subject to frequent temperature change, due to the negligible coefficient of expansion of the fiberglass. The fiberglass sheets are easier to cut and drill and are not subject to the rust and oxidation that steel and aluminum undergo.

This technique is also useful in the forming of epoxy tooling. Plastic sheet is obtainable in a variety of thicknesses, shapes, and sizes. It has been used successfully to bond laminates on bulkheads and to mount legs and casters on square tubing and angles.

Source: G. H. Erickson of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17077)

*No further documentation is available.*

### SOFT ALLOY WIPER DIES FOR TUBE FORMING

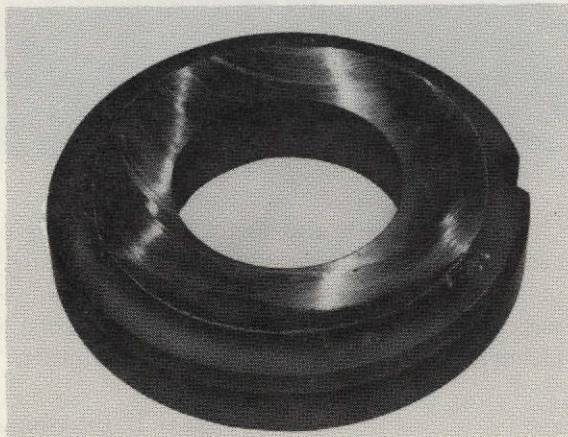


In tube forming, machined steel dies suffer deformation through constant use. This necessitates the manufacture of a new die, including the expensive machining process. In this innovation, a relatively soft alloy of bismuth is used for the wiping dies. The alloy is melted and poured into a precision mold. No machining is necessary; and after repeated use has deformed the die, it is again melted down and then recast.

Source: C. W. Seiple of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17051)

*No further documentation is available.*

### SALVAGE OF WORN FEMALE DIES



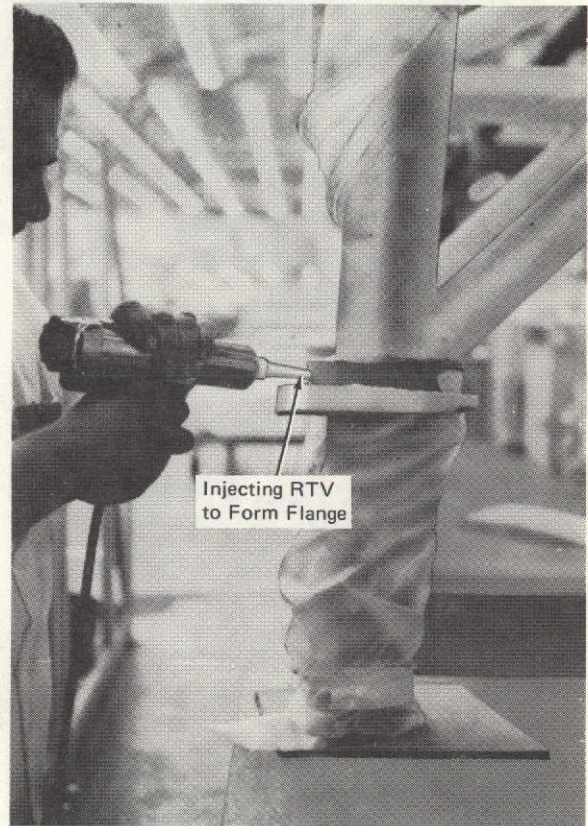
Reclaimed Punch Die

This novel method permits reclaiming of female punch dies that have become worn beyond usefulness for production work. A tool-steel plate is welded on top of the worn die, and the assembly is set up as it is used in normal punching. The added plate is then punched through with a mating hole die to obtain a close-fitting female die. Flame hardening and sharpening of the new surface complete the process, and the die is ready for use. Thickness of the added plate is according to the final hole diameter.

Source: H. Z. Lewis of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17717)

*No further documentation is available.*

## CORK MOLD FOR ROOM TEMPERATURE VULCANIZING (RTV) ELASTOMER INJECTION



Inexpensive, high-density cork molds have been successfully used in room temperature vulcanizing processes. They exhibit distinct economic and fabrication advantages in comparison with conventional plastic, wood, or metal molds. Figures 1 and 2 illustrate the injection molding of an RTV flange using this technique.

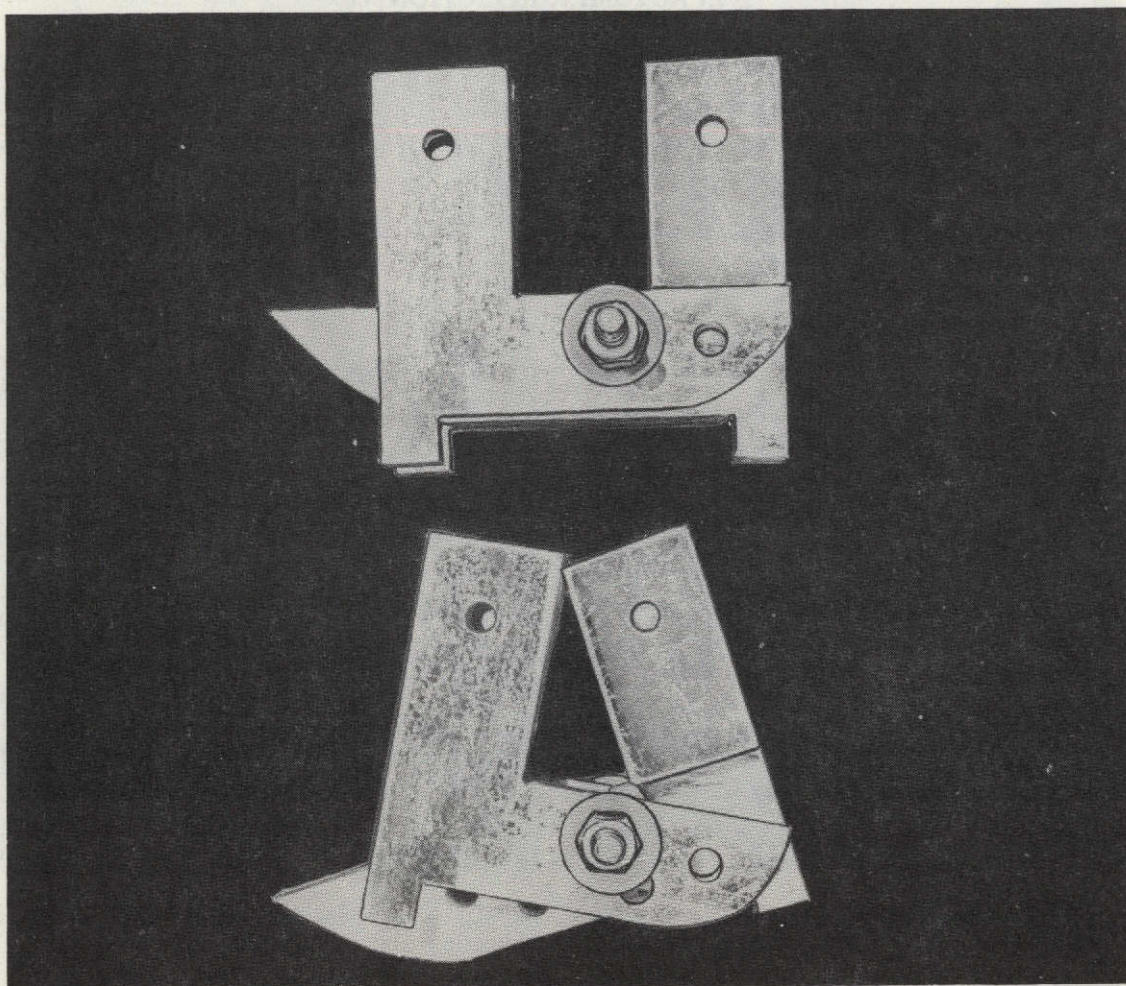
The molds are economical to fabricate and simple to machine. They can be made using simple hand tools such as knives, saws, scissors, and files; and the cork can be bonded together using commercial

adhesives. It is available in various thicknesses without laminations and can be machined, drilled, sanded, or sculptured into irregular shapes. Because of its high density, the cork provides an excellent parting agent for most injection materials.

Source: W. F. Reynolds of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17317)

*No further documentation is available.*

## FORMING DIE COMPENSATES FOR SPRING-BACK



This shop aid (see fig.) greatly reduces the forming time of detail parts made of hard steel wire or rod. Setting of the die and brake ram permits the operator to make his calculations only once with the knowledge that all subsequent parts will be identical with the first that is formed. Using the brake without this forming die required that each individual part be checked for tolerance.

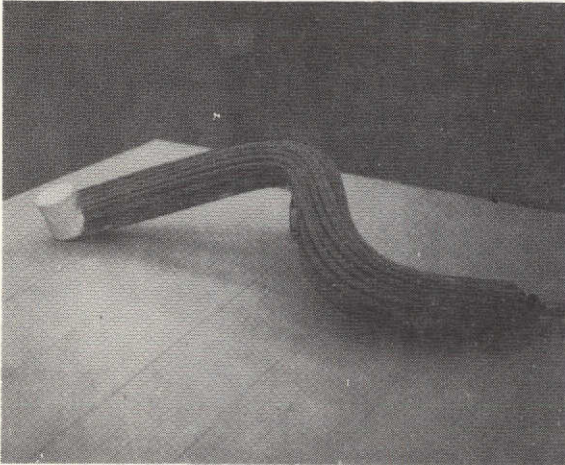
The die can be used whenever an inexpensive tool is needed to fabricate wire parts and the spring-back factor, while forming, is critical.

Source: C. J. Hull and J. Dotson of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17576)

*No further documentation is available.*

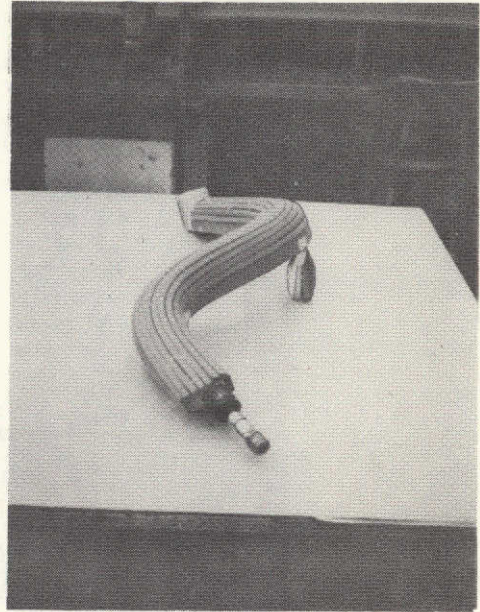
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## ABLATIVE CORK MOLDING PROCESS



This process involves fabrication of ablatively cork covering for tubular ducting prior to final shaping of the ducting. The method is termed the "strip and cover" process and consists of cutting the cork into thin strips and attaching it to the substrate before shaping. Use of thin strips permits the user to follow the contour of the substrate surface while maintaining a high degree of surface coverage.

Previous methods used cork sheeting formed in a prearranged configuration. These were more expensive and less satisfactory than the "strip and cover" process, due to the time and cost savings of the latter. Additionally, after bending the tubular substrate to its final form (see fig.), the cork strips maintain high shear and tensile strength.

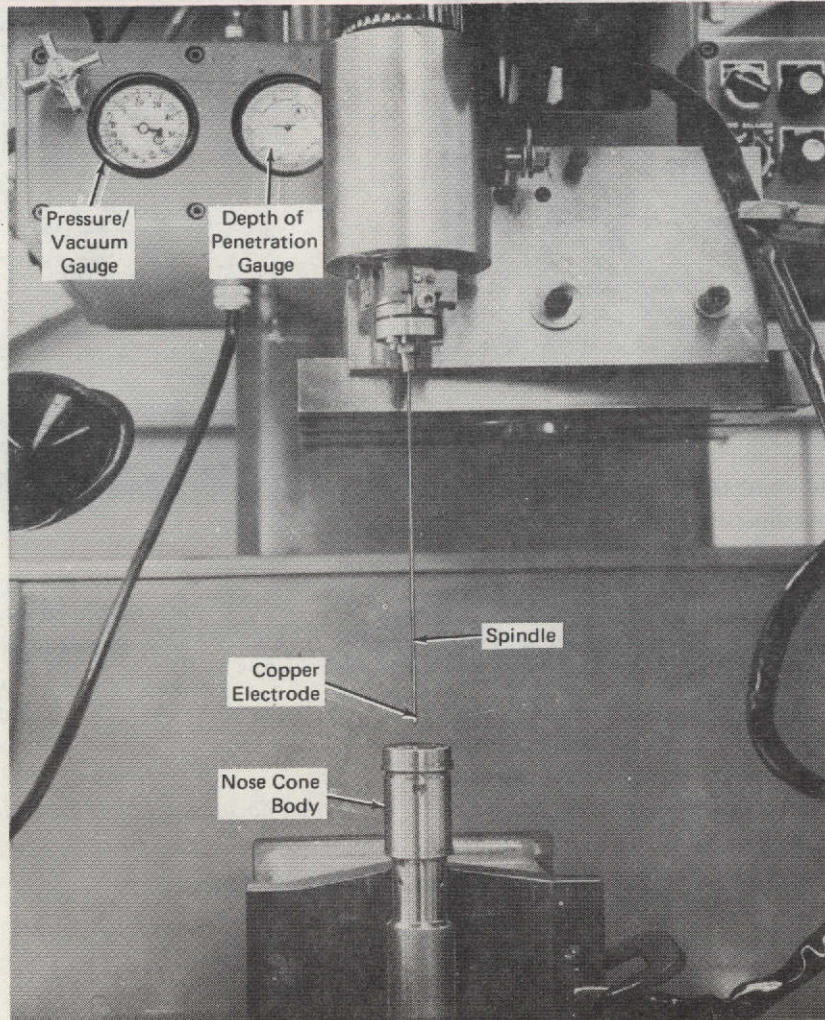


Source: W. F. Reynolds, Jr. of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17775)

*No further documentation is available.*

## Section 2. Material Cutting Methods

### DEEP-HOLE MACHINING TECHNIQUES FOR DIFFICULT-TO-MACHINE MATERIALS



Manufacture of a 304 stainless steel nose cone for a sounding probe required that five 0.060 in. (0.15 cm) diameter holes, 7.5 in. (19 cm) deep be machined in the probe. The tolerance on the diameter of the holes was 0.001 in. (0.0025 cm), and the tolerance on the location of the holes was 0.005 in. (0.013 cm). The 0.060 in. holes had to intersect with five 0.040 in. (0.092 cm) diameter holes located 45° off the centerline of the 0.060 in. holes. Therefore, for all practical purposes, the 0.060 in.

diameter holes can be considered blind holes, 125 diameters deep. Due to the toughness of 304 stainless steel, the nose cone could not be drilled by any known conventional method.

Electrical Discharge Machining (E.D.M.) was utilized to machine the holes in the nose probe. A special rotating spindle (see fig.) was fabricated to hold the electrode. Two dovetailed slides 90° apart were attached to the end of the spindle to provide a method for centering the upper end of the electrode.

A ball joint attached to the underside of the dove-tailed slides provided a method for centering the lower end of the electrode. This combination of dove-tailed slides and ball joint provides the flexibility necessary to align the electrode with the nose probe. Hole location is stepped off by moving the work table of the E.D.M. machine. The rotating spindle is hollow to provide a means of forcing dielectric flushing oil through the electrode.

The copper electrode includes a 7.5 in. (19 cm) long solid carbide tube to which the electrode copper tubing is soldered. Carbide tubing is necessary for the electrode shank since it is a very rigid material and provides a thin rigid means of holding the copper electrode. Tubing must be used for the shank and the electrode in order to force the dielectric oil to the bottom of the hole where the eroding action takes place. The oil is forced through the rotating spindle, through the carbide tube electrode shank and out the lower end of the electrode. This provides the flushing

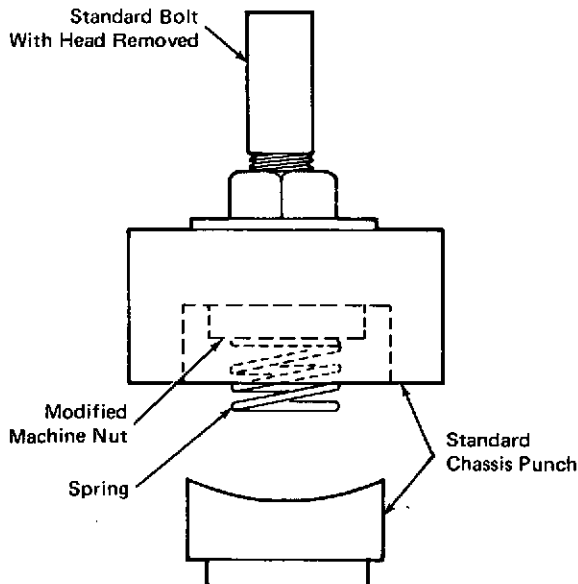
action so necessary in E.D.M. operations. A thin piece of copper wire is placed in the end of the copper electrode to erode away the core which is formed as the hole is eroded. This core will give a great deal of difficulty if it is allowed to form. The copper wire is bent so it will not be pushed out of the electrode by the flow of the dielectric flushing oil. The wire must be large enough in diameter to completely erode away the core, but small enough to allow sufficient flushing oil to flow out the lower end of the electrode.

The rotating electrode generates a round straight hole in the same manner that a boring bar generates a round straight hole, the only difference being in the cutting action.

Source: Edmund Smigocki  
Goddard Space Flight Center  
(GSC-11141)

*No further documentation is available.*

## ABRASIVE SHEET DISK CUTTER



This innovation involves a modified machine nut, a bolt, and a spring (see fig.) that are assembled and mounted in the chuck of a lever-operated drill press. A sheet of abrasive cloth is fed across a standard chassis punch mounted on the drill press table, and the drill press lever is pulled down to perform the disk-cutting operation. As the drill press lever is returned to its "up" position, the spring in the modified machine nut ejects the cut disk. With this simple tool, one man can cut a great number of abrasive cloth disks in a very short time. The process is simple and inexpensive and lends itself to a situation requiring large numbers of disks at infrequent intervals, a situation that cannot justify expensive tooling.

Source: M. H. Cope of  
Bendix Corp.  
under contract to  
Kennedy Space Center  
(KSC-10767)

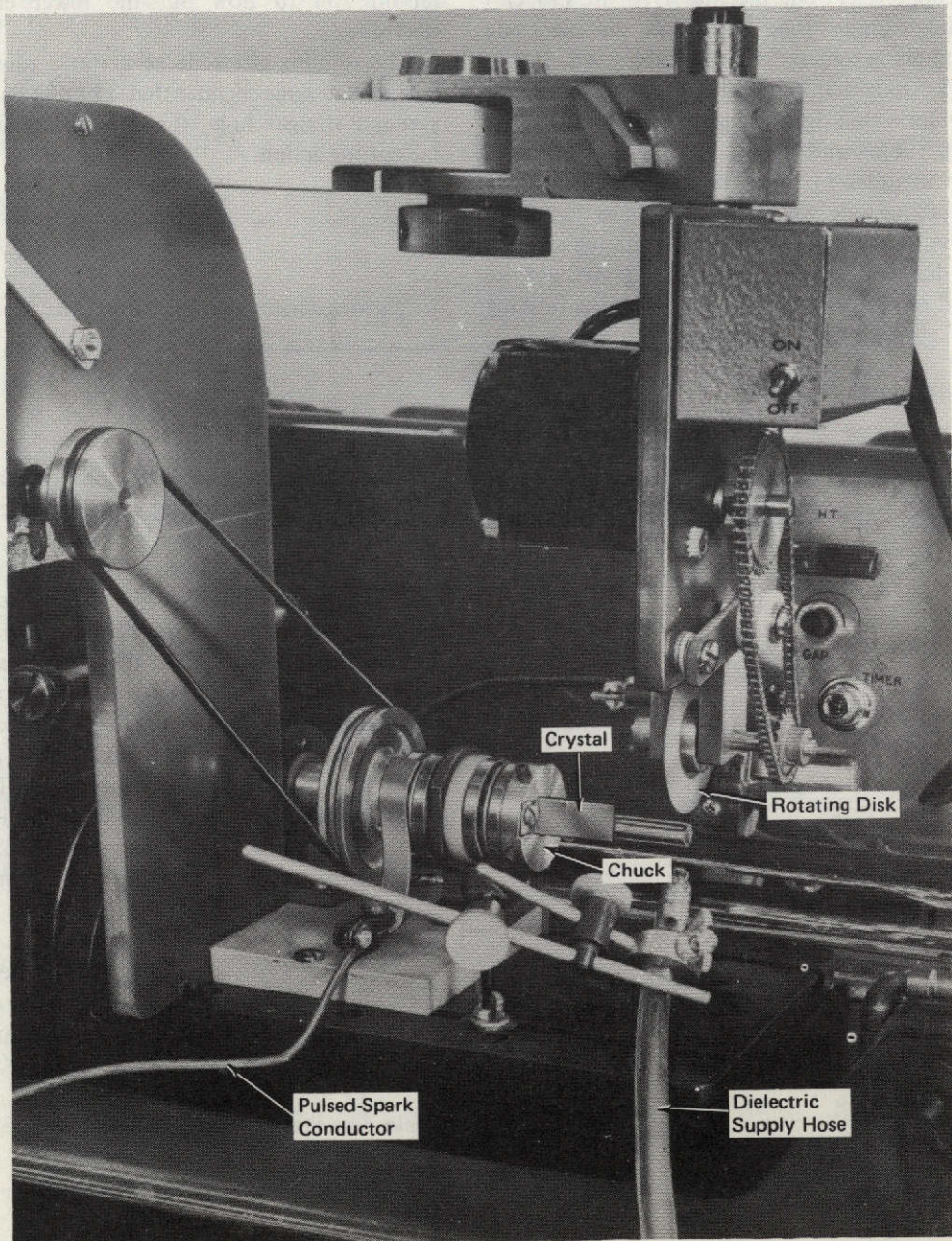
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### ROTATING DISK SLICER FOR SPARK EROSION CUTTER

This device is a modification of a spark-erosion cutter designed to cut crystals into parallel slices without deforming the crystal structure. In this application, the workpiece (crystal) is held in a four-jaw chuck and rotated in one direction while the rotating disk turns in the opposite direction.

Cutting action is achieved by high-current, timed spark pulses delivered to the crystal (the anode),

through the dielectric-filled gap to the rotating disk (cathode) in a path that is aligned to effect precise material removal from the crystal. With both tool and workpiece rotating, the machine will not start "hunting" on the last part of the cutting. It will make a clean, almost perfectly smooth cut, leaving only a small raised tip, in the center, which is easily polished off.



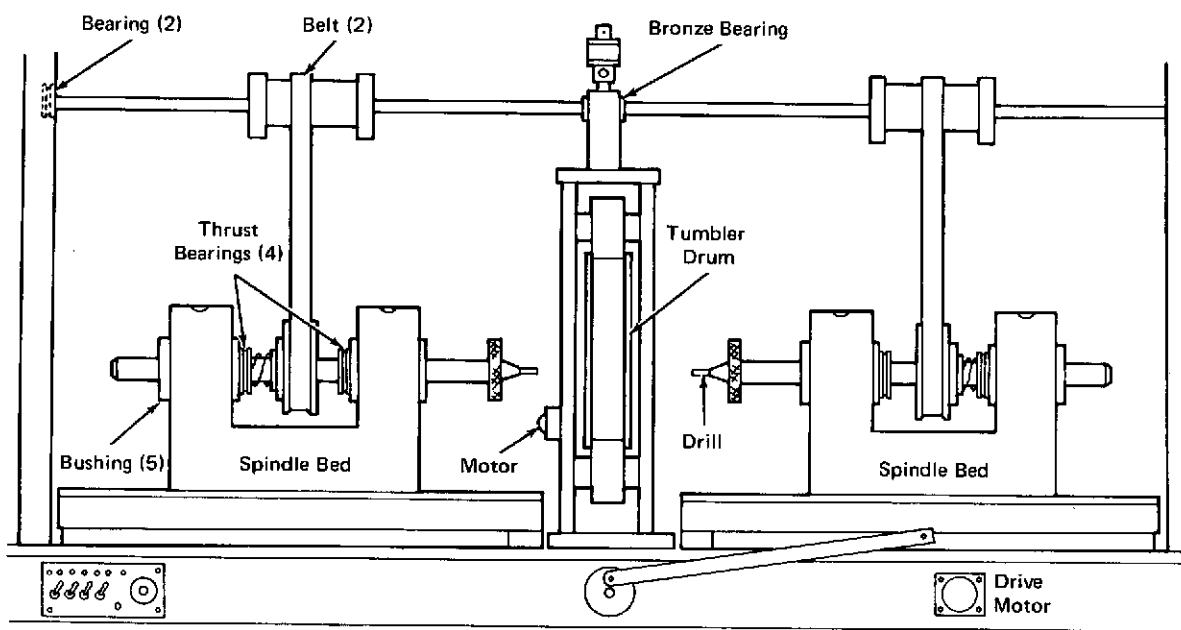
This system of cutting reduces the cutting time previously required (6 hours) to 45 minutes. Adjusting the slicer to various angles enables the operator to cut crystals into a variety of cone shapes. Small rectangles can also be cut to produce thin slices in much less time than with a stationary blade. The

rotating disk slicer has also been employed to cut a variety of metals with the same satisfactory results.

Source: J. A. Patenaude  
Lawrence Berkeley Laboratory  
(LRL-10051)

*No further documentation is available.*

## QUARTZ BORING MACHINE



The boring of long, accurate, small-diameter holes in extremely hard materials has been a tedious, manual process requiring many hours of labor and frequent changing of drill bits. A device has been developed which reduces the equipment used, substantially reduces drilling time, and provides semi-automatic operation.

Essentially, the quartz boring machine (see fig.) consists of a tumbler drum drive frame flanked by two spindle heads mounted on individual spindle beds. The spindle heads which hold the drill bits move in opposition to one another, alternately converging on and diverging from the work, which is held in the tumbler drum. When the spindle heads converge, the diamond drills simultaneously drill the

work from both sides. At the same time, the work is slowly revolving in the tumbler drum, to help maintain precise alignment of the drills. Simultaneous drilling from opposite sides of the work measurably reduces drilling time over conventional methods.

The device may be of interest to persons or firms involved with the drilling of glass, ceramics, or quartz.

Source: D. E. Sawlor of  
Massachusetts Institute of Technology  
under contract to  
Johnson Space Center  
(MSC-11110)

*Circle 4 on Reader Service Card.*

## DEEP ETCH METHOD OF MARKING METALS

Impression stamping of metals for parts or lot identification reduces fatigue life or distorts the surfaces. Ordinary electrolytic etching is so shallow that it is removed through heat treating and does not show on anodic-coated aluminum.

This innovation involves a deep etch electrolyte used in conjunction with an electric discharge device set on dc at full current. Although sharp clear etches were accomplished, none of the following metals or alloys are attacked intergranularly: 321 CRES; 347

TABLE

## MAXIMUM DEPTH OF ETCHING

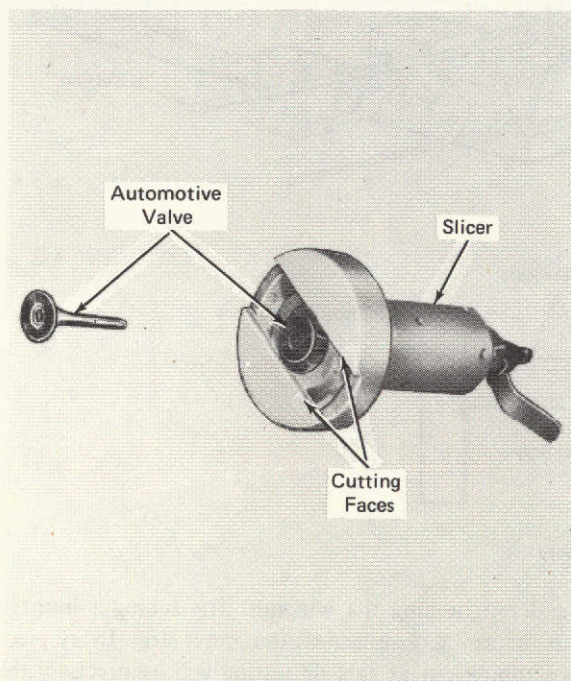
Material	Depth In Inches (In mm)				Recommended Time In Seconds
	5 Sec.	10 Sec.	20 Sec.	30 Sec.	
2024-T3	0.00056 (0.014224)	0.00075 (0.019050)	0.00169 (0.042926)	0.00282 (0.071628)	10
6061-T6	0.00094 (0.023876)	0.00189 (0.048006)	0.00142 (0.036068)	0.00142 (0.036068)	10
7075-T73	0.00118 (0.029972)	0.00142 (0.036068)	0.00189 (0.048006)	0.00142 (0.036068)	7
OFHC Copper	0.00018 (0.004572)	0.00018 (0.004572)	0.000282 (0.0071628)	0.000282 (0.0071628)	20
4130	0.00037 (0.009398)	0.00088 (0.022352)	0.00155 (0.039370)	0.00235 (0.059690)	10
347 CRES	0 (0)	0.00142 (0.036068)	0.00189 (0.048006)	0.00237 (0.060198)	20
321 CRES	0.00009 (0.002286)	0.00140 (0.035560)	0.00166 (0.042164)	0.00280 (0.071120)	20
A286	0.00094 (0.023876)	0.00142 (0.036068)	0.00284 (0.072136)	0.00284 (0.072136)	10
X-750	0.00094 (0.023876)	0.00119 (0.030226)	0.00142 (0.036068)	0.00213 (0.054102)	10
Rene 41	0.00113 (0.028702)	0.00150 (0.038100)	0.00196 (0.049784)	0.00280 (0.071120)	10
Inconel 718	0.00142 (0.036068)	0.00189 (0.048006)	0.00237 (0.060198)	0.00273 (0.069342)	20
Hastelloy C	0.00056 (0.014224)	0.00154 (0.039116)	0.00150 (0.038100)	0.00300 (0.076200)	20

CRES; A286; Inco 718; X-750; Rene 41; Hastelloy C; 4130; 6061-T6; 2024-T3; 7075-T73; and OFHC Copper. The depth of etching did not exceed 0.003 in. (0.0762 mm). Thus, the deep etch can be used safely with any of the above metals or alloys. The table presents the recommended times for etching the various metals and alloys.

Source: A. Townhill of  
Rockwell International Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-19063)

*Circle 5 on Reader Service Card.*

### SLICER FOR ELASTOMERIC ADHESIVE SURFACES



Spray-foam butt joints on cryogenic fluid, tank-insulation closeouts require an elastomeric adhesive material for an interface. When the closeouts are spray foamed, excess adhesive must be machined flush with the basic foam insulation surface. The protruding elastomeric adhesive cannot be sanded down, due to its rubbery composition.

The rotary, surface slicer (see fig.) is controlled as to depth of cut by use of a standard automotive exhaust valve, which is seated in the center of the tool, in a position depressed beyond the cutting surface to the desired depth-of-cut position. Although the tool tends to dull rapidly during operation, it is easily resharpened with common tools. Any conventional compressed air source can be used to drive the tool.

Source: C. T. Davison of  
Rockwell International Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-16953)

*Circle 6 on Reader Service Card.*

### CUTTER DESIGN AND MACHINING TECHNIQUES FOR CRES HONEYCOMB PANELS

In joining CRES (corrosion resistant steel) honeycomb panels, cutting back the panel edges and removing the braze alloy must be done precisely in order to assure a good weld. This innovation provides a uniform, consistent set-back distance through special spring-loaded cutting tools mounted on the same skate tool with which the panel was originally cut to size.

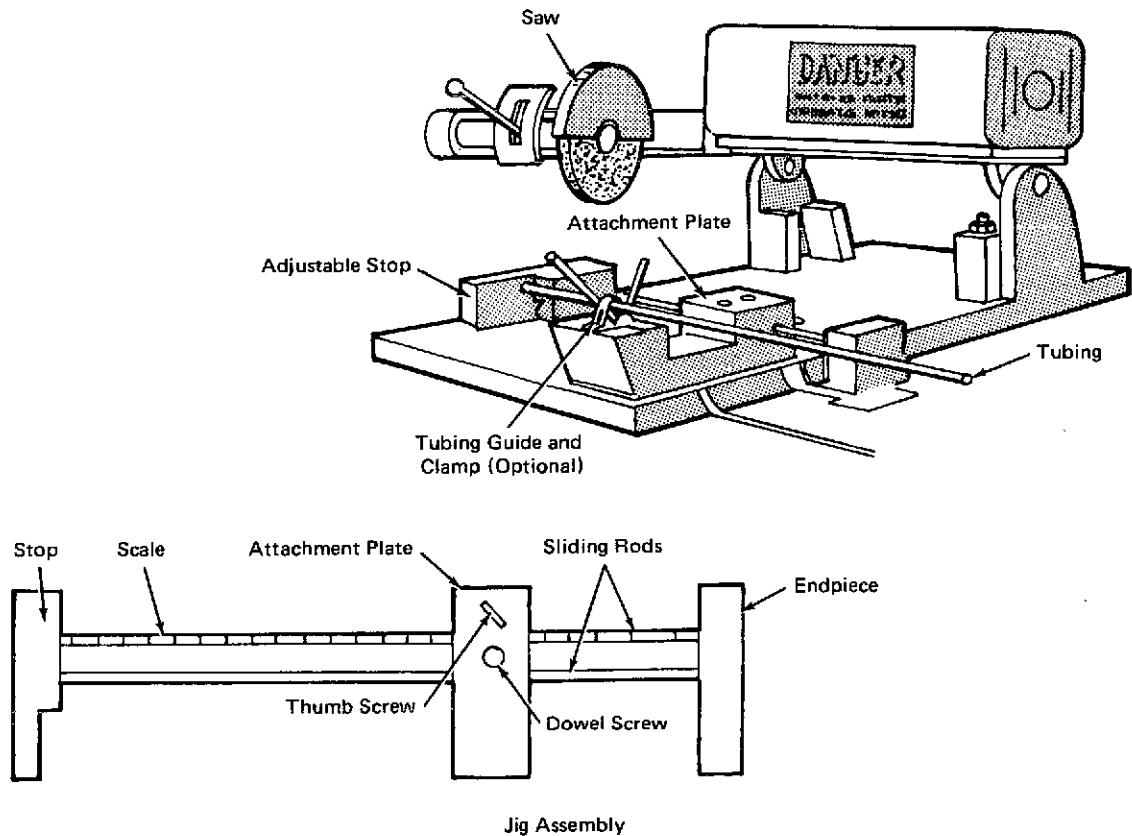
Normally, the core is cut back from the edge of the panel, in one pass, a sufficient amount to expose the panel face for welding. However, in this

operation, two passes are used to remove sufficient core and the braze alloy. A third (finish) cut deburrs the face, removing any irregularities left by the previous cuts.

Source: D. D. Kern of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17045)

*Circle 7 on Reader Service Card.*

## ADJUSTABLE SAW JIG FOR UNIFORM TUBING LENGTHS



This device permits the operator to cut, on a production basis, lengths of tubing used for cable transitions and protective shields for instrumentation transducers and leads. The lengths of tubing must be cut precisely as to length and cross section.

A flat attachment plate, dowel, and wingnut are used to attach the jig to the saw (see fig.). The jig assembly consists of a stop and two rods which slide in the attachment plate. One of the rods is scored to provide a gauge for measuring tube length. Adjustment is obtained by loosening the wingnut, sliding the rod and stop assembly to the desired position,

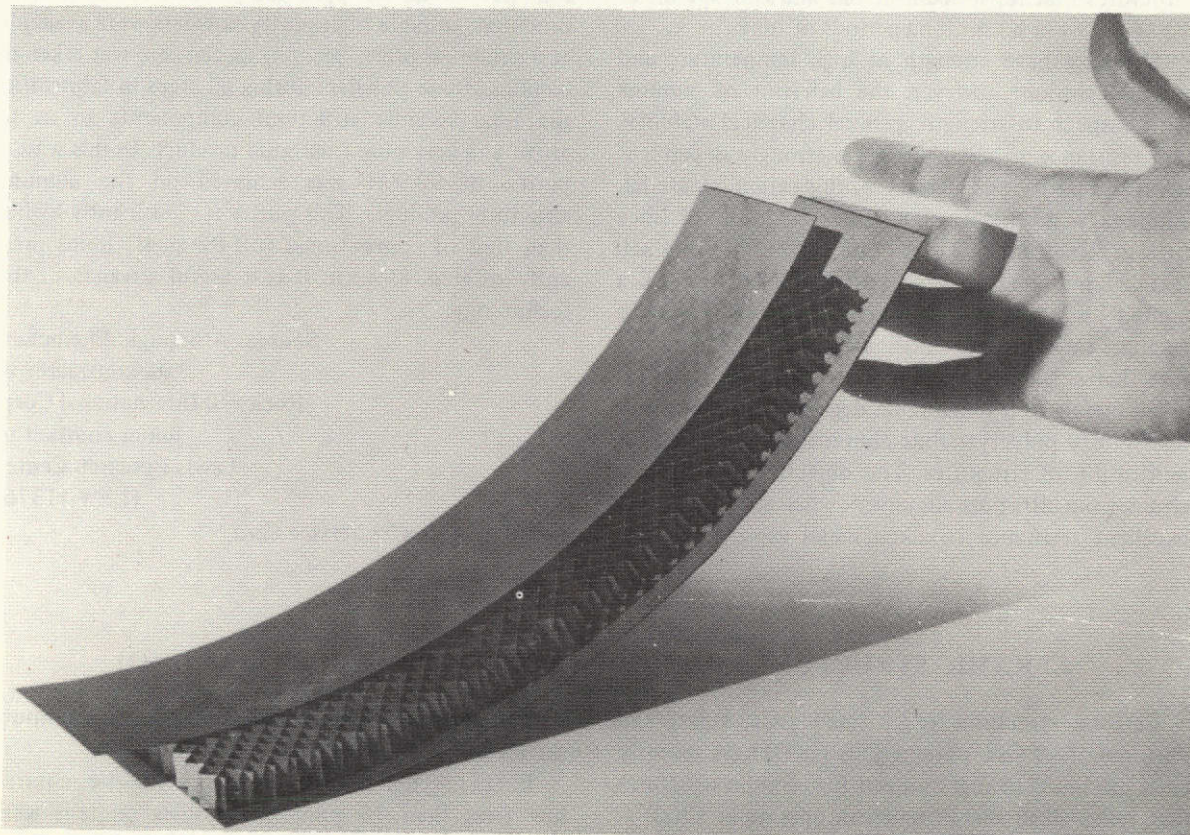
and retightening the wingnut. The tubing is inserted in the saw groove against the preset stop. Every piece of tubing cut at this jig setting will be precisely the same size. This method can be used for indexed cutting of many differently shaped parts.

Source: L. J. Similer of  
Westinghouse Astronuclear Laboratory  
under contract to  
Space Nuclear Systems Office  
(NUC-10025)

*No further documentation is available.*

## Section 3. Shaping and Fabrication Techniques

### MATCHING FLAT, BERYLLIUM HONEYCOMB BLANKETS AND FLAT FACINGS TO PRODUCE MATCHED CONTOURED COMPONENTS



Contoured sandwich panels and mating components from beryllium core blankets and flat facings have been creep-formed at 1300° F (977 K) to produce dimensionally-stable and stress-free assemblies. A test was performed to evaluate the possibility of performing the panel components (core, faces, and channels) for brazing into the final 10-ft. (3.05-m) radius configuration.

Core contouring presented the only unknown in preforming of panel components. Several pieces of beryllium ingot foil were hot formed to an approximate 1 ft. (0.305 m) radius. Results indicated the "as-welded" core had sufficient strength to be formed over this much tighter 1:10 radius. Test results showed the welded core could be formed with the ribbon in either the "L" or "T" direction. Based on these encouraging results, components for a 3 ft. (0.92 m) x 12 ft. (3.66 m) panel were formed to a 4 ft. (1.22 m) radius of curvature in one operation.

These components were then combined with two 3-inch (0.076-m) long U-channels and assembled for brazing.

Standard cleaning and loading procedures were followed and the assembly was brazed at 1460° F (1065 K). Excellent braze flow and fillets were observed on the "as-brazed" panel as shown in the figure. The favorable results were confirmed by radiograph. The structure remained stable throughout the braze cycle and conformed at finish to the 4 ft. (1.22 m) radius of curvature.

Source: L. A. Grant, L. F. Kamper, and  
G. D. Cremer of  
International Harvester Co.  
under contract to  
Marshall Space Flight Center  
(MFS-21352)

*Circle 8 on Reader Service Card.*

### CERAMIC STRUCTURES MADE FROM VERY HIGH PURITY ALUMINA ( $\text{Al}_2\text{O}_3$ )

Ceramic structures (e.g., small rods, rings, and buttons) of 99.99% pure alumina ( $\text{Al}_2\text{O}_3$ ) have recently been produced to meet a need for ceramic structures that resist alkali metals and can operate at  $1200^\circ\text{C}$  ( $1473\text{ K}$ ) for long periods of time.

Ceramics have strength at high temperature and resist corrosion; however, the behavior of alumina with respect to strength, general chemical stability, and resistance to alkali metals is strongly dependent upon the purity and density of this ceramic material. Alumina with the usual commercial levels of silica (0.1 to 2 percent  $\text{SiO}_2$ ) is quite susceptible to alkali metal liquid and/or vapor attack. That the silica content is a critical factor in the ability of this ceramic to withstand alkali metals is shown by the fact that single crystal alumina resists the attack of alkali metals to a remarkable degree. Therefore, very high purity polycrystalline alumina was specified for fabrication of structures. The objective was to construct, from ultra pure alumina powder, structures with excellent resistance to alkali metal vapor, and with

high strength and low porosity for maximum service life.

First, alumina starting powders with the required low (less than 50 ppm  $\text{SiO}_2$ ) silica content were procured; suitable high purity powders were available at a premium price. Second, special care was taken in handling these powders during all steps in fabricating the final ceramic structural components so as to arrive at a very pure final solid product. In this way, a purity of 99.99% was achieved on the alumina structural products. This purity is significantly higher than that of conventional (off-the-shelf) items presently offered; as such, it is a useful advance in the technology.

Source: Atomergic Chemetals,  
subcontractor to  
Rockwell International Corp.  
under contract to  
Lewis Research Center  
(LEW-11376)

*Circle 9 on Reader Service Card.*

### CERAMIC STRUCTURES MADE FROM ULTRA PURE BERYLLIA ( $\text{BeO}$ )

Ceramic structures (e.g., small rods, rings, and buttons) of 99.98% pure beryllia ( $\text{BeO}$ ) have recently been produced to meet a need for ceramic structures that resist alkali metals and can operate at  $1200^\circ\text{C}$  ( $1473\text{ K}$ ) for long periods of time.

Ceramics have strength at high temperature and resist corrosion; however, the behavior of beryllia with respect to strength, general chemical stability, and resistance to alkali metals is strongly dependent upon the purity and density of this ceramic material. Beryllia with the usual commercial levels of silica (0.1 to 2 percent  $\text{SiO}_2$ ) is quite susceptible to alkali metal liquid and/or vapor attack. That the silica content is a critical factor in the ability of this ceramic to withstand alkali metals is shown by the fact that single crystal beryllia resists the attack of alkali metals to a remarkable degree. Therefore, very high purity polycrystalline beryllia was specified for fabrication of structures. The objective was to construct, from ultra pure beryllia powder, structures with excellent resistance to alkali metal vapor, and

with high strength and low porosity for maximum service life.

First, beryllia starting powders with the required low (less than 75 ppm  $\text{SiO}_2$ ) silica content were procured; suitable high purity powders were available at a premium price. Second, special care was taken in handling these powders during all steps in fabricating the final ceramic structural components so as to arrive at a very pure final solid product. In this way, a purity of 99.98% was achieved on the beryllia structural products. This purity is significantly higher than that of conventional (off-the-shelf) items presently offered; as such, it is a useful advance in the technology.

Source: National Beryllia Corp.  
subcontractor to  
Rockwell International Corp.  
under contract to  
Lewis Research Center  
(LEW-11377)

*Circle 10 on Reader Service Card.*

## CONTINUOUS ICE PROCESS FOR COILING TUBING

A technique was developed to bend double-tube-type boiler tube sub-assemblies into a coil without contaminating the internal tube surfaces. The double-tube sub-assemblies consisted of a 1-inch (25.4-mm) O.D. x 0.35-inch (8.89-mm) wall, stainless

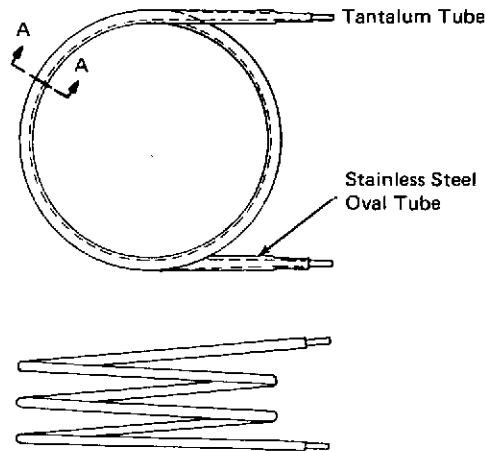
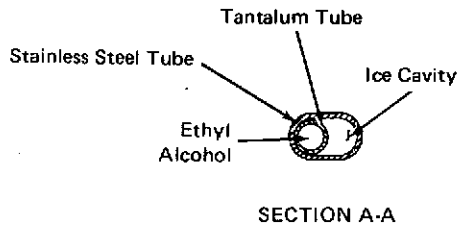


Figure 1. Coiled Tube

steel outer tube, which had been flattened to an oval shape with inside measurements of 0.78 inch (19.8 mm) x 1.03 inches (26.16 mm), and a 3/4-inch (19.05-mm) O.D. tantalum inner tube. They were assembled in 38-foot (11.59-m) lengths with the tantalum tube positioned as shown in Figure 1, Section A-A, and bent into a coil approximately 4 feet (1.22 m) in diameter with the long axis of the oval-shaped outer tube perpendicular to the coil axes (Figure 1). Differential thermal expansion at operating temperature required that the inner tantalum tube be positioned at the maximum radius permitted by the outer tube after coiling. The operating fluids used in the boiler, mercury and NaK, required very clean internal tube surfaces, and prohibited the use of sand, rosin, eutectic metals, etc., which are conventionally used to fill tubes during bending operations to prevent them from distorting.

To coil the tube assembly, a uniform dense medium was needed between the tantalum and stainless steel tubes to transmit the bending loads. This was achieved by sealing the lower end of the outer tube and flooding the space between the outer and inner tubes with distilled water. The water was subsequently frozen to produce a solid ice filler. Freezing was begun at the lower end and progressed upward thus forcing out the excess water. Alcohol was cooled to 15° F (264 K) by passing it through dry ice and then forced upward through the tanta-

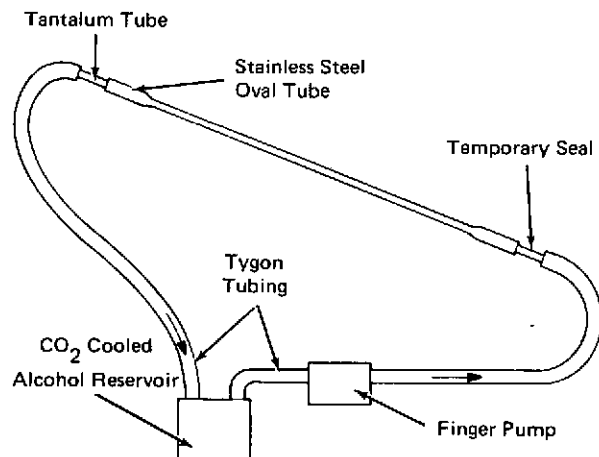


Figure 2. Coiling Process

lum tube (Figure 2). The coiling process was accomplished in multiple passes, which maintained the freezing of ice on a continuous basis and imposed no time constraints on the process. The tubes were bent into a coil, allowed to warm up, and the water and alcohol drained off.

Source: L. W. Gertsma, J. W. Slough,  
E. R. Furman, and D. W. Medvid  
Lewis Research Center  
(LEW-10390)

*No further documentation is available.*

## FABRICATION PROCESS FOR BEADED-SKIN STRUCTURAL PANELS

An analysis of primary-structure panel concepts for hypersonic vehicle wings showed that the tubular and beaded-skin panel concepts were best. When fabricated from the nickel-base alloy Rene 41 they were two of the most efficient and lowest-weight panel configurations. These two panel configurations are illustrated in the figure. The tubular concept consists of two corrugated sheets spotwelded together; the beaded-skin panel consists of one sheet.

These new panel configurations require a deep-formed bead to attain their structural efficiency. To attain the required elongations, multistage forming operations were necessary. Available specifications do not state the formability limits for Rene 41 nor do they provide sufficient control over gauge tolerance and chemical or mechanical properties to ensure consistent formability.

The formability limits of Rene 41 were established by performing stretch beading, flanging, bending, and draw forming operations on test coupons. The coupons were formed under high pressure in forming tools equipped with positive-lock draw rings. Limits for forming in the annealed condition were established; after interstage annealing, second, third, and fourth forming state limits were determined.

The table below shows the results of the room-temperature stretch beading tests, on Rene 41 alloy.

Gauge, in. (mm)	No. of Process Anneals*	Recommended Max. Total Elong., %
0.010(0.254)–0.020(0.508)	1	17.0
0.010(0.254)–0.020(0.508)	2	25.0
0.010(0.254)–0.020(0.508)	3	30.0
0.025(0.635)–0.030(0.762)	1	20.0
0.025(0.635)–0.030(0.762)	2	30.0
0.025(0.635)–0.030(0.762)	3	36.0
0.025(0.635)–0.030(0.762)	4	40.0

\*1950°F (1339 K) to 1975°F (1353 K) for 15 minutes; cool to 1000°F (811 K) within 3 seconds.

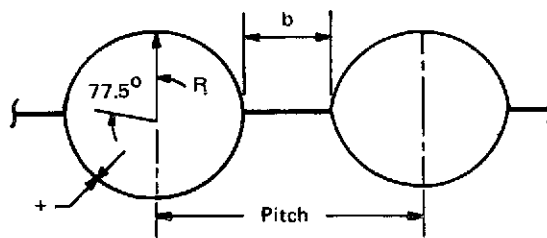
For the gauges involved in this program, elongations up to 20% can be achieved in a single operation from the solution-treated condition. Elongations over 20% require interstage annealing.

Annealing was accomplished by two different methods. One method was to encase the blanks in a sealed stainless steel envelope so that annealing in an air furnace would not oxidize the coupon. The envelope was removed for the final forming stage. The second method used a hydrogen-atmosphere

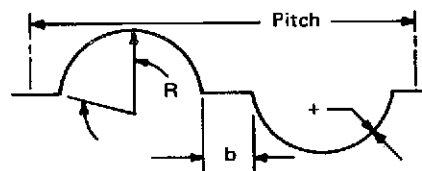
bright annealing furnace. No appreciable difference in forming between the two methods was noted.

From the coupon tests the full size panel fabrication techniques were devised. The two corrugated sheets for the tubular panel were formed in a high-pressure press that forced the Rene 41 sheet into a metal die that had six bead cavities.

The beaded panel was formed by hydraulic forming in a heavy duty press using auxiliary pumps for fluid movements. Tooling for this panel consisted of two flat face blocks each having three internal beads. The bead cavities in the blocks were staggered, so that when the die faces came together the cavities formed the panel cross section.



Tubular Panel Concept



Beaded-Skin Panel Concept

### PANEL CONCEPTS

The detailed fabrication process for forming the beaded skin is described below.

- Shear 32.0 in. (81.28 cm) x 38.0 in. (96.52 cm) blank from 0.020 in. (0.058 mm) gage Rene 41
- Deburr
- Clean: alkaline wash, pickle, rinse dry
- Form sheet using form die, first stage @ 2000 psi ( $13.79 \times 10^6$  N/m<sup>2</sup>), approximately 20%
- Degrease
- Anneal 1950° F (1340 K) to 2000° F (1370 K) in an air furnace for 10 minutes, air blast cool to 1000° F (810 K) within 3 seconds
- Descale: deoxidize, nitric-hydrofluoric pickle, rinse, oven dry
- Form sheet using form die, final stage @ 3000

- psi ( $20.68 \times 10^6 \text{ N/m}^2$ ), approximately 15%
- Lay out finish panel dimensions and shear
- Final clean prior to assembly
- Assemble doubler by resistance welding
- Remove electrode deposit: chromic acid followed by alcohol rinse
- Age and heat oxidize at  $1400^\circ \text{ F}$  ( $1030 \text{ K}$ ) for 16 hours in air furnace using ceramic fixtures for heating and air cooling.

The cleaning process (descal) was required to ensure scale-free parts because a large hydrogen-

atmosphere furnace was not available. Fusion and resistance welding of Rene 41 should be done in the solution-treated (annealed) condition prior to aging.

Source: K. A. Wilhelm of  
Lockheed Missiles & Space Co.  
under contract to  
Langley Research Center  
(LAR-10692)

*No further documentation is available.*

### METHOD PRODUCES LONG NARROW SLIT IN THIN-WALLED METAL STRUCTURE

This is a fabrication technique that involves a series of steps to achieve a precise slit in a thin-walled ( $0.001 \text{ in.}$  ( $0.0254 \text{ mm}$ )) metal member. The slit is used as a fluidic element to provide a means of sensing the position of a gyroscopic rotor, a surface of which partially covers the slit.

The gyro case function requires a hole leading to a cavity behind a thin wall, through which there is a long narrow slit. A fixture (see Fig. 1) is utilized to

layer of nickel (see Fig. 2). The nickel surface is then machined to a distance of  $0.001 \text{ in.}$  ( $0.0254 \text{ mm}$ ) from the edges of the  $0.010 \text{ in.}$  ( $0.254 \text{ mm}$ ) thick shims. This results in exposure of the  $0.002 \text{ in.}$  ( $0.0508 \text{ mm}$ ) shim, flush with the machine-finished nickel surface. After melting out the metal alloy from the hole and cavity, the shims are removed by a selective, chemical etching process, completing the part (see Fig. 3).

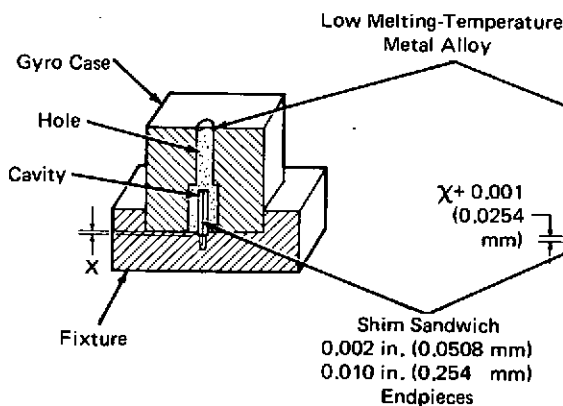


Figure 1

accurately position a sandwich of three metal shims relative to the case. After installation of the shims in the fixture and after location of the fixture on the case, the hole and cavity are cast full of a low-melting-temperature metal alloy. After solidification of the cast metal, the fixture is removed, and the gyro case (with encapsulated shims) is electroplated with a thick  $0.010 \text{ in.}$  ( $0.254 \text{ mm}$ ) to  $0.015 \text{ in.}$  ( $0.381 \text{ mm}$ )

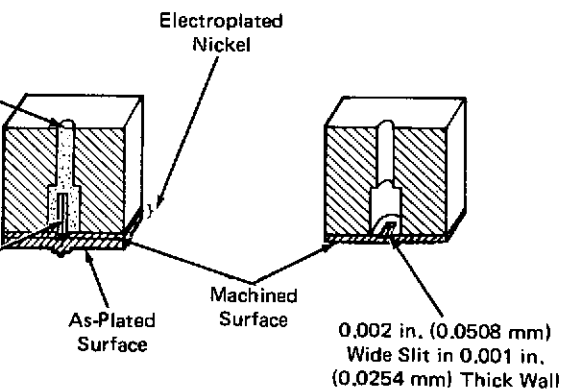


Figure 2.

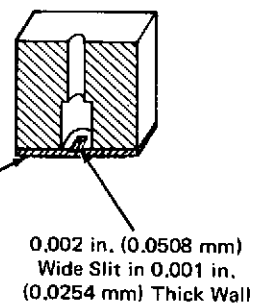


Figure 3.

Source: P. A. Christopher, W. J. Gross,  
W. H. Henley, and B. D. Swirsky of  
Conductron Corp.  
under contract to  
Langley Research Center  
(LAR-10409)

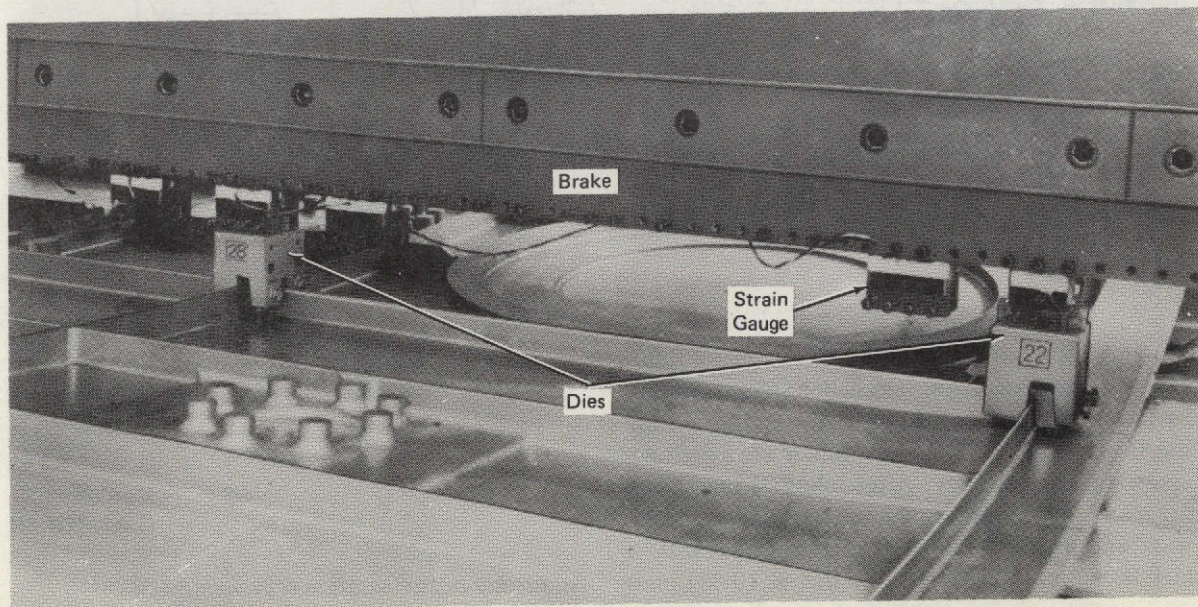
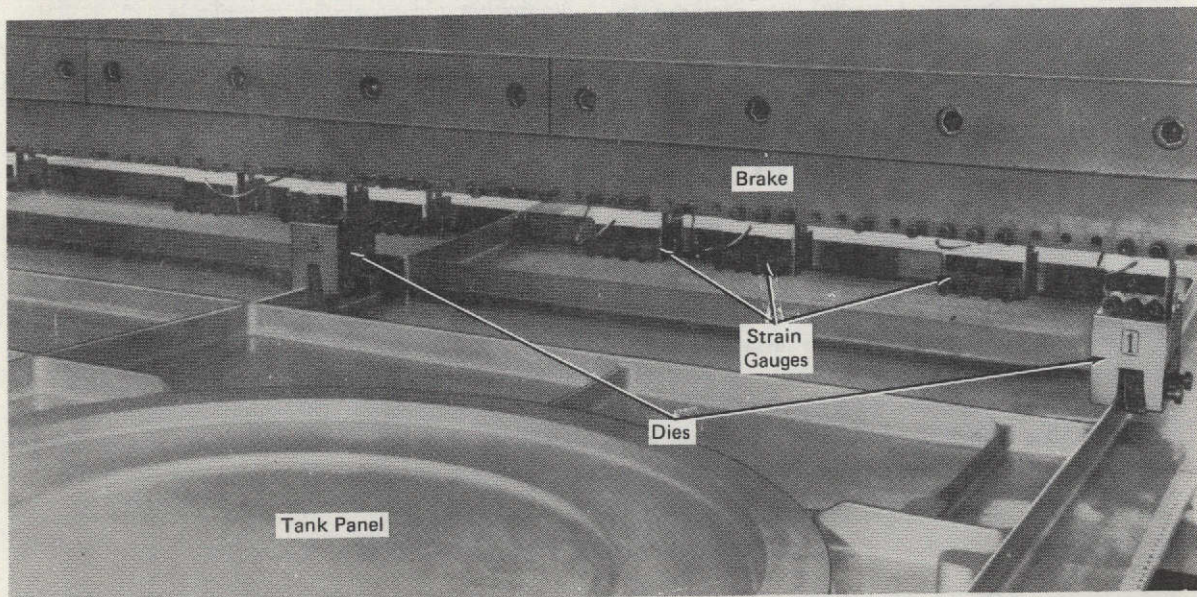
*No further documentation is available.*

### BRAKE-FORMING OF PANELS WITH INTEGRALLY MACHINED RIBS

It has been found that special straddled dies and strain-gauge instrumentation can be used with pilot panels to accurately form cylindrical tank panels that have integral waffle-pattern ribs.

Uniquely designed dies are used to support the integrally machined circumferential ribs of the Saturn II LH<sub>2</sub> tank cylinder panels during brake-forming

(see figs.). The dimensions of the gaps in the dies vary to fit several rib thicknesses. The minimum die clearance (closed) must be 0.006 in. (0.152 mm) to prevent damage to the ribs during forming. The maximum die clearance could not exceed 0.010 in. (0.254 mm) to prevent rippling of the ribs during forming.



The panels are fed through the brake in 1/2-inch (1.27 cm) increments. This feed is controlled by attaching 1/2-inch, incrementally marked tape to the two circumferential edges of the panel.

The one way straddle dies are used to support and brake form the circumferential rib in the bay area, between the vertical stringers only (dies 1 and 5, Fig. 1).

The three way straddle dies are used to support and brake form the circumferential rib at the vertical stringer end intersection (die 22, Fig. 2). The four way straddle dies are used to support and form the circumferential rib at the intersection of the vertical stringer only (die 28, Fig. 2). These dies are attached

to the brake ram by the conventional method. Development of these dies and the required brake load sequence was accomplished by use of load cells on the press brake and strain gauges on the pilot production panels. Load cells were used to determine and specify the tonnage required for each stroke of the brake. Strain-gauge instrumentation was used to prevent overstressing the panel.

Source: P. Fears and J. H. Stewart of  
Rockwell International Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-16389)

*Circle 11 on Reader Service Card.*

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## Section 4. Materials Characteristics Data

### BETA-FIBER FABRIC SEWING INSTRUCTIONS

These instructions cover cutting and sewing operations with Beta-fiber fabrics on which a non-combustible finish has been applied. The instructions treat cutting the fabric, sewing thread, thread tension, needle selection, sewing equipment, seaming, stitch length, and similar details.

These sewing instructions are applicable to the fabrication of a variety of items made of glass cloth treated with a noncombustible finish. Items such as protective clothing, fire curtains, and bag house filters are included. While these instructions are preliminary

due to limited experience with sewing Beta-fiber fabric to date, the sewing technology is being used to produce finished goods.

Source: J. R. Buben of  
Owens-Corning Fiberglas Co.  
under contract to  
Johnson Space Center  
(MSC-14023)

*Circle 12 on Reader Service Card.*

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### TEST PROGRAM TO DETERMINE MACHINABILITY OF GLASS-IMPREGNATED LAMINATES

This test program sought to establish the condition of glass-impregnated laminates after drilling with high-speed steel drills and with solid carbide drills. The sample blocks were drilled both wet (with a coolant) and dry, and with both masonite and

aluminum backup plates. Upon completion of the test drilling, ultrasonic inspection was used to determine if any delamination had occurred.

The table shows the results, which indicate that no delamination occurred upon entrance or exit of

#### VISUAL EXAMINATION AND FINDINGS FROM SECTIONED PORTIONS USING A 10-POWER MAGNIFIER

Test Block No. 1 (Hole No.)	Condition: Machined High-Speed Steel Drill	Type Backup: 1/4-in. (6.35-mm)	Remarks
1	Dry	Masonite	No Delamination
5	Dry	Masonite	Delamination on Entrance
11	Dry	Aluminum	Clean
15	Dry	Aluminum	Delamination on Exit
6	Wet	Masonite	Clean
10	Wet	Masonite	Delamination on Exit
16	Wet	Aluminum	Clean
20	Wet	Aluminum	Delamination on Exit
Test Block No. 2 (Hole No.)	Condition: Machined Solid Carbide Drill	Type Backup: 1/4-in. (6.35-mm)	Remarks
1	Dry	Masonite	Clean
5	Dry	Masonite	Clean
11	Dry	Aluminum	Clean
15	Dry	Aluminum	Clean
6	Wet	Masonite	Clean
10	Wet	Masonite	Clean
16	Wet	Aluminum	Clean
20	Wet	Aluminum	Clean
Test Block No. 3 (Hole No.)	Condition: Machines High-Speed Steel Drill	Type Backup: 1/4-in. (6.35-mm)	Remarks
1	Dry	Masonite	Delamination on Exit
5	Dry	Masonite	Delamination on Exit
11	Dry	Aluminum	Delamination on Both Ends
15	Dry	Aluminum	Delamination on Both Ends
6	Wet	Masonite	Delamination on Exit
10	Wet	Masonite	Delamination on Exit
16	Wet	Aluminum	Delamination on Both Ends
20	Wet	Aluminum	Delamination on Both Ends

the solid carbide drills, but delamination did occur upon both entrance and exit of the high-speed steel drills. The application of a coolant appeared to offer no advantage, while the use of a securely attached backup plate considerably reduced material delamination during drill exit.

Source: L. E. Grant of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17085)

Circle 13 on Reader Service Card.

## BENDING CHARACTERISTICS OF TYPE I ABLATIVE CORK SHEETING

A matrix and graph for determining the bending characteristics of various thicknesses of Type I ablative cork sheeting have been developed and used for fabrication and assembly of the boost cover for the Apollo Command Module.

Previously, the thickness of the cork selected was left to the discretion of the individual worker. If too thick a sheet was selected, the cork would crack and would either have to be scrapped or the crack filled with a powdered adhesive. This led to a tendency to use thin sheets, resulting in an excessive number of laminates. Use of the new data for sheet forming will result in a reduction in scrap and in a decrease in labor time. The data is presented in the following table and in the figure.

### BENDING CHARACTERISTICS OF TYPE I CORK SHEETING

(See Figure)

Cork Thickness	Minimum Bend Radius
0.020 in. (0.051 cm)	0.15 in. (0.381 cm)
0.050 in. (0.127 cm)	0.36 in. (0.914 cm)
0.100 in. (0.254 cm)	0.66 in. (1.676 cm)
0.200 in. (0.508 cm)	1.06 in. (2.692 cm)
0.250 in. (0.635 cm)	1.20 in. (3.048 cm)
0.300 in. (0.762 cm)	1.33 in. (3.378 cm)
0.400 in. (1.016 cm)	1.61 in. (4.089 cm)
0.500 in. (1.270 cm)	1.89 in. (4.801 cm)
0.600 in. (1.524 cm)	2.17 in. (5.512 cm)
0.700 in. (1.778 cm)	2.45 in. (6.223 cm)
0.800 in. (2.032 cm)	2.73 in. (6.934 cm)
0.900 in. (2.286 cm)	3.28 in. (8.331 cm)

It includes a delineation of the minimum bend radius for each thickness of Type I cork sheeting and a mathematically based method for determining the precise number of cork laminates required to reach a

desired cover thickness for a given bend radius. The data was determined experimentally by bending cork sheets of various thicknesses. The sheets were bent in 1/4 inch (0.635 cm) intervals, and an arc was drawn around each bend. This was continued until visible cracking was noted in the cork surface. The last arc drawn prior to cracking was selected as the maximum allowable bend, and the corresponding minimum bend

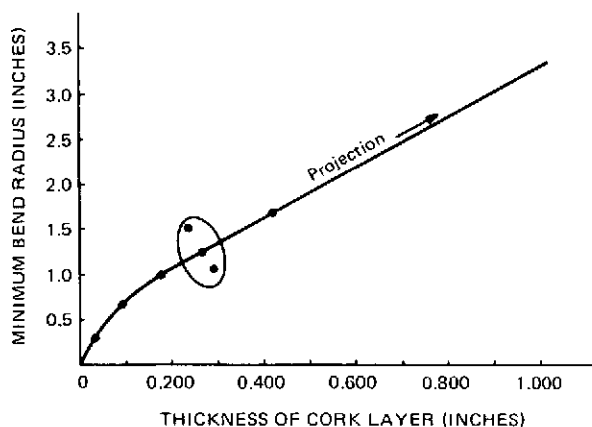


Figure 1. Bending Characteristics of Type I Cork Sheeting

radius was geometrically determined. When the arc was elliptical rather than round, the longest radius was used to provide a safety factor. The data was then tabulated and presented in both a graph and a matrix format.

Source: V. H. Cousins of  
Rockwell International Corp.  
under contract to  
Johnson Space Center  
(MSC-17229)

No further documentation is available.

## Patent Information

The following innovations, described in this Compilation, have been patented or are being considered for patent action as indicated below:

**Method Produces Long Narrow Slit in Thin-Walled Metal Structure (Page 21) LAR-10409**

Inquiries concerning rights for the commercial use of this invention should be addressed to:

Patent Counsel  
Langley Research Center  
Code 456  
Hampton, Virginia 23665

**Beta-Fiber Fabric Sewing Instructions (Page 23) MSC-14023**

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457 (f)], to the Owens-Corning Fiberglas Co., Fiberglas Tower, Toledo, Ohio 43601.

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